11-06-06

IFW

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	10/593,848
Filing Date	21 September 2006
First Named Inventor	Lee, ChangHee
Art Unit	
Examiner Name	
Attorney Docket Number	5489.P092

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☒ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☒ Other Enclosure(s) (please Identify below): Return Receipt Postcard

Remarks

1 Cert Copy 2004-24465 (Korea)
1 Cert Copy PCT/US2005/011886 (PCT)

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	BST&Z LLP 12400 Wilshire Boulevard, Seventh Floor, Los Angeles, CA 90025-1030		
Signature			
Printed name	Lester J. Vincent		
Date	November 2, 2006	Reg. No.	31,460

EXPRESS MAIL
EV 839873765

TRANSMISSION/MAILING

I hereby state that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as Express Mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Theresa Joenks		
Typed or printed name	Theresa Joenks	Date	11/2/06

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

P2 1524858

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

October 20, 2006

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY OF THE BELOW IDENTIFIED INTERNATIONAL APPLICATION AS ORIGINALLY FILED AND ANY CORRECTIONS THERETO FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE ACTING AS A RECEIVING OFFICE UNDER THE PATENT COOPERATION TREATY.

APPLICATION NUMBER: ***PCT/US05/11886***
FILING DATE: ***April 08, 2005***

By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office

G. Montgomery

W. MONTGOMERY
Certifying Officer

TRANSMITTAL LETTER TO THE UNITED STATES RECEIVING OFFICE

Date	8 April 2005
International Application No.	*****
Attorney Docket No.	5489.P092PCT

I. Certification under 37 CFR 1.10 (if applicable)

EV 469 984 733 US	8 April 2005
Express Mail mailing number	Date of Deposit

I hereby certify that the application/correspondence attached hereto is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Mail Stop PCT, Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450.

Signature of person mailing correspondence	Jennifer C. Pask
	Typed or printed name of person mailing correspondence

II. ☒ **New International Application**

TITLE	WAVELENGTH DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORK HAVING MULTIPLE BRANCHES OF OPTICAL DISTRIBUTION

Earliest priority date (Day/Month/Year): 9 April 2004

SCREENING DISCLOSURE INFORMATION: In order to assist in screening the accompanying international application for purposes of determining whether a license for foreign transmittal should and could be granted and for other purposes, the following information is supplied. (Note: check as many boxes as apply):

A. ☐ The invention disclosed was **not** made in the United States.

B. ☒ There is no prior U.S. application relating to this invention.

C. ☐ The following prior U.S. application(s) contain subject matter which is related to the invention disclosed in the attached international application. (*NOTE: priority to these applications may or may not be claimed on form PCT/RO/101 (Request) and this listing does not constitute a claim for priority.*)

application no.		filed on	
application no.		filed on	

D. ☐ The present international application contains additional subject matter not found in the prior U.S. application(s) identified in paragraph C. above. The additional subject matter is found on pages ____

and ☐ **DOES NOT ALTER** ☐ **MIGHT BE CONSIDERED TO ALTER** the general nature of the invention in a manner which would require the U.S. application to have been made available for inspection by the appropriate defense agencies under 35 U.S.C. 181 and 37 CFR 5.1. See 37 CFR 5.15.

III. ☐ **A Response to an Invitation from the RO/US.** The following document(s) is (are) enclosed:

A. ☐ A Request for An Extension of Time to File a Response

B. ☐ A Power of Attorney (General or Regular)

C. ☐ Replacement pages:

pages		of the request (PCT/RO/101)	pages		of the figures
pages		of the description	pages		of the abstract
pages		of the claims			

D. ☐ Submission of Priority Documents

Priority document		Priority document	

E. ☐ Fees as specified on attached Fee Calculation sheet form PCT/RO/101 annex

IV. ☐ **A Request for Rectification under PCT 91** ☐ **A Petition** ☐ **A Sequence Listing Diskette**

V. ☐ **Other** (please specify):

The person signing this form is the:	☐ Applicant	Lester J. Vincent
	☒ Attorney/Agent (Reg. No.) 31,460	Typed name of signer
	☐ Common Representative	Signature

PCT/US05/11886

Home Copy PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/US 05/11886

International Filing Date: 08 APRIL 2005 (08.04.05)

Name of receiving Office and "PCT International Application": PCT INTERNATIONAL APPLICATION RO/US

Applicant's or agent's file reference (if desired) (12 characters maximum): 5489.P092PCT

Box No. I TITLE OF INVENTION

WAVELENGTH DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORK HAVING MULTIPLE BRANCHES OF OPTICAL DISTRIBUTION

Box No. II APPLICANT ☐ This person is also inventor

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

NOVERA OPTICS, INC.
480 S. California Avenue
Suite 305
Palo Alto, CA 94306-1609
US

Telephone No.

Facsimile No.

Teleprinter No.

Applicant's registration No. with the Office

State *(that is, country)* of nationality: US

State *(that is, country)* of residence: US

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

LEE, Chang-Hee
110-102 Hanwol Apt., Shinsung-dong
Yusong-gu, Taejon
South Korea

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality: KR

State *(that is, country)* of residence: KR

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

VINCENT, Lester J.
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP
12400 Wilshire Boulevard, 7th Floor
Los Angeles, California 90025
US

Telephone No. 408 720 8300

Facsimile No. 408 720 8383

Teleprinter No.

Agent's registration No. with the Office 31,460

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

LIM, Dong-Sung
105-1703 Expo Apt., Jeonmin-dong
Yuseong, Daejeon 305-761
South Korea

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality: KR

State *(that is, country)* of residence: KR

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Supplemental Box *If the Supplemental Box is not used, this sheet should not be included in the request.*

1. *If, in any of the Boxes, except Boxes Nos. VIII(i) to (v) for which a special continuation box is provided, the space is insufficient to furnish all the information: in such case, write "Continuation of Box No...." (indicate the number of the Box) and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:*

   (i) if more than two persons are to be indicated as applicants and/or inventors and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;

   (ii) if, in Box No. II or in any of the sub-boxes of Box No. III, the indication "the States indicated in the Supplemental Box" is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;

   (iii) if, in Box No. II or in any of the sub-boxes of Box No. III, the inventor or the inventor/applicant is not inventor for the purposes of all designated States or for the purposes of the United States of America: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;

   (iv) if, in addition to the agent(s) indicated in Box No. IV, there are further agents: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box No. IV;

   (v) if, in Box No. VI, there are more than three earlier applications whose priority is claimed: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI.

2. *If the applicant intends to make an indication of the wish that the international application be treated, in certain designated States, as an application for a patent of addition, certificate of addition, inventor's certificate of addition or utility certificate of addition: in such a case, write the name or two-letter code of each designated State concerned and the indication "patent of addition," "certificate of addition," "inventor's certificate of addition" or "utility certificate of addition," the number of the parent application or parent patent or other parent grant and the date of grant of the parent patent or other patent grant or the date of filing of the parent application (Rules 4.11(a)(iii) and 49bis.1(a) or (b)).*

3. *If the applicant intends to make an indication of the wish that the international application be treated, in the United States of America, as a continuation or continuation-in-part of an earlier application: in such a case, write "United States of America" or "US" and the indication "continuation" or "continuation-in-part" and the number and the filing date of the parent application (Rules 4.11(a)(iv) and 49bis.1(d)).*

Continuation of Box No. IV

Amini, Farzad E.; Babbitt, William Thomas; Becker, Jordan Michael; Bemadicou, Michael A.; Blakely, Roger W. Jr.; Caldwell, Gregory D.; Coester, Thomas M.; De Vos, Daniel M.; Fahmi, Tarek N.; Ferrill, Thomas S.; Go, James Y.; Holloway, Sheryl Sue; Willmore F. Holbrow, III; Hoover, George W II; Hyman, Eric S.; Mallie, Michael J.; Mendonsa, Paul A.; Nguyen, Thinh V.; O'Rourke, Robert; Ovanezian, Daniel E.; Schaal, William W.; Scheller, James C., Jr.; Sokoloff, Stanley W.; Szepesi, Judith A.; Taylor, Edwin H.; Vincent, Lester J.; Ward, John Patrick; and Zafman, Norman; my patent attorneys, and Henry, James A.; my patent agent, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (408) 720-8300,; and James R. Thein, my patent attorney.

Box No. V DESIGNATIONS

The filing of this request **constitutes under Rule 4.9(a), the designation** of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.

However,

☐ DE Germany **is not designated** for any kind of national protection

☒ KR Republic of Korea **is not designated** for any kind of national protection

☐ RU Russian Federation **is not designated** for any kind of national protection

(The check-boxes above may be used to exclude (irrevocably) the designations concerned in order to avoid the ceasing of the effect, under the national law, of an earlier national application from which priority is claimed. See the Notes to Box No. V as to the consequences of such national law provisions in these and certain other States.)

Box No. VI PRIORITY CLAIM

The priority of the following earlier application(s) is hereby claimed:

Filing date of earlier application *(day/month/year)*	Number of earlier application	Where earlier application is:		
		national application: country or Member of WTO	regional application:* regional Office	international application: receiving Office
item (1) 09 April 2004 (09.04.2004)	2004-24465	KR		
item (2)				
item (3)				

☐ Further priority claims are indicated in the Supplemental Box.

The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of this international application is the receiving Office)* identified above as:

☐ all items ☐ item (1) ☐ item (2) ☐ item (3) ☐ other, see Supplemental Box

* *Where the earlier application is an ARIPO application, indicate at least one country party to the Paris Convention for the Protection of Industrial Property or one Member of the World Trade Organization for which that earlier application was filed (Rule 4.10(b)(ii)):* . . . .

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*:

ISA / EP

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority)*:

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII DECLARATIONS

The following **declarations** are contained in Boxes Nos. VIII (i) to (v) *(mark the applicable check-boxes below and indicate in the right column the number of each type of declaration)*:		Number of declarations
☐ Box No. VIII (i)	Declaration as to the identity of the inventor :	
☐ Box No. VIII (ii)	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent :	
☐ Box No. VIII (iii)	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application :	
☐ Box No. VIII (iv)	Declaration of inventorship (only for the purposes of the designation of the United States of America) :	
☐ Box No. VIII (v)	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty :	

Box No. IX CHECK LIST; LANGUAGE OF FILING

This international application contains:

(a) in paper form, the following number of sheets:

request (including declaration sheets)	:	5
description (excluding sequence listing and/or tables related thereto)	:	27
claims	:	8
abstract	:	1
drawings	:	5
Sub-total number of sheets	:	46
sequence listing	:	
tables related thereto	:	
(for both, actual number of sheets if filed in paper form, whether or not also filed in computer readable form; see (c) below)		
Total number of sheets	:	46

(b) ☐ only in computer readable form (Section 801(a)(i))
- (i) ☐ sequence listing
- (ii) ☐ tables related thereto

(c) ☐ also in computer readable form (Section 801(a)(ii))
- (i) ☐ sequence listing
- (ii) ☐ tables related thereto

Type and number of carriers (diskette, CD-ROM, CD-R or other) on which are contained the
- ☐ sequence listing: .....
- ☐ tables related thereto: .....

(additional copies to be indicated under items 9(ii) and/or 10(ii), in right column)

This international application is accompanied by the following item(s) *(mark the applicable check-boxes below and indicate in right column the number of each item):*

		Number of items
1. ☒	fee calculation sheet	:
2. ☐	original separate power of attorney	:
3. ☐	original general power of attorney	:
4. ☐	copy of general power of attorney; reference number, if any:	:
5. ☐	statement explaining lack of signature	:
6. ☐	priority document(s) identified in Box No. VI as item(s):	:
7. ☐	translation of international application into *(language)*:	:
8. ☐	separate indications concerning deposited microorganism or other biological material	:
9. ☐	sequence listing in computer readable form *(indicate type and number of carriers)*	
(i) ☐	copy submitted for the purposes of international search under Rule 13*ter* only (and not as part of the international application)	:
(ii) ☐	*(only where check-box (b)(i) or (c)(i) is marked in left column)* additional copies including, where applicable, the copy for the purposes of international search under Rule 13*ter*	:
(iii) ☐	together with relevant statement as to the identity of the copy or copies with the sequence listing mentioned in left column	:
10. ☐	tables in computer readable form related to sequence listing *(indicate type and number of carriers)*	
(i) ☐	copy submitted for the purposes of international search under Section 802(b-*quater*) only (and not as part of the international application)	:
(ii) ☐	*(only where check-box (b)(ii) or (c)(ii) is marked in left column)* additional copies including, where applicable, the copy for the purposes of international search under Section 802(b-*quater*)	:
(iii) ☐	together with relevant statement as to the identity of the copy or copies with the tables mentioned in left column	:
11. ☒	other *(specify)*: Return postcard	:

Figure of the drawings which should accompany the abstract:	Language of filing of the international application: English

Box No. X SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Lester J. Vincent

For receiving Office use only

1. Date of actual receipt of the purported international application: JC10 Rec'd PCT/PTO 08 APR 2005 (08.04.05)	2. Drawings: ☐ received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	☐ not received:
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority (if two or more are competent): ISA / EP	6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

PCT/US05/11886

This sheet is not part of and does not count as a sheet of the international application.

PCT

FEE CALCULATION SHEET

Annex to the Request

For receiving Office use only

International Application No. PCT/US 05/11886

08 APRIL 2005 (08.04.05)

Date stamp of the receiving Office

Applicant's or agent's file reference: 5489.P092PCT

Applicant: NOVERA OPTICS, INC.

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE	$300.00 T	300
2. SEARCH FEE	$2,075.00	2075

International search to be carried out by EP

(If two or more International Searching Authorities are competent to carry out the international search, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FILING FEE

Where items (b) and/or (c) of Box No. IX apply, enter **Sub-total number of sheets**: 46
Where items (b) and (c) of Box No. IX do not apply, enter **Total number of sheets**

i1 first 30 sheets	$1,211.00 i1	1211
i2 16 (number of sheets in excess of 30) x 13 (fee per sheet) =	$208.00 i2	
i3 additional component (only if sequence listing and/or tables related thereto are filed in computer readable form under Section 801(a)(i), or both in that form and on paper, under Section 801(a)(ii)): 400 x _____ (fee per sheet) =	i3	
Add amounts entered at i1, i2 and i3 and enter total at I	$1,419.00 I	

(Applicants from certain States are entitled to a reduction of 75% of the international filing fee. Where the applicant is (or all applicants are) so entitled, the total to be entered at I is 25% of the international filing fee.)

4. FEE FOR PRIORITY DOCUMENT *(if applicable)*	P	
5. TOTAL FEES PAYABLE Add amounts entered at T, S, I and P, and enter total in the TOTAL box	$3,794.00 TOTAL	3794

MODE OF PAYMENT

- [X] authorization to charge deposit account (see below)
- [ ] postal money order
- [ ] cash
- [ ] coupons
- [X] cheque
- [ ] bank draft
- [ ] revenue stamps
- [ ] other *(specify)*:

AUTHORIZATION TO CHARGE (OR CREDIT) DEPOSIT ACCOUNT

(This mode of payment may not be available at all receiving Offices)

- [ ] Authorization to charge the total fees indicated above.
- [X] *(This check-box may be marked only if the conditions for deposit accounts of the receiving Office so permit)* Authorization to charge any deficiency or credit any overpayment in the total fees indicated above.
- [ ] Authorization to charge the fee for priority document.

Receiving Office: RO/ US

Deposit Account No.: 02-2666

Date: 8 April 2005

Name: Lester J. Vincent

Signature: Lester J Vincent

WAVELENGTH DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORK HAVING MULTIPLE BRANCHES OF OPTICAL DISTRIBUTION

Field

[0001] Embodiments of the invention relate generally to a passive optical network (PON), and more particularly, to a wavelength division multiplexing passive optical network (WDM-PON) having multiple branches of optical distribution.

Background

[0002] FIG. 1 is a block diagram illustrating the structure of a conventional WDM-PON. Referring to FIG. 1, the conventional WDM-PON includes a central office 100, an optical distribution network 142 and optical network units 140-1, 140-2,..., and 140-N (hereinafter, commonly designated as 140).

[0003] The conventional WDM-PON performs bi-directional communication by using two different wavelength bands. For instance, a downstream signal is transmitted from the central office 100 to the optical network unit 140 through an A wavelength band, such as 1570-1620 nanometers. An upstream signal is transmitted from the optical network

unit 140 to the central office 100 through a B wavelength band, such as 1450-1500 nanometers.

[0004] The central office 100 includes a plurality of optical transmitters 101, 102 and 103 for transmitting downstream signals having an A wavelength band, a plurality of optical receivers 104, 105 and 106 for receiving upstream signals having a B wavelength band, a plurality of band division filters 107, 108 and 109 for coupling/decoupling light having an A wavelength band to/from light having a B wavelength band, and a 1 x N multiplexer/demultiplexer 110, wherein N represents the number of optical network units.

[0005] The optical unit network 140 includes a plurality of optical transmitters 118, 119 and 120 for transmitting upstream signals having a B wavelength band, a plurality of optical receivers 115, 116 and 117 for receiving downstream signals having an A wavelength band, and a plurality of band division filters 121, 122 and 123 for coupling/decoupling light having an A wavelength band to/from light having a B wavelength band.

[0006] The optical distribution network 142 is located between the central office 100 and the optical network units 140-1 to 140-N and includes a first-branch optical cable 113 for transmitting optical signals having multiplexed wavelengths from the central office 100 to a remote node 150, a 1 x N multiplexer/demultiplexer 114 for

multiplexing/demultiplexing optical signals transmitted thereto from the central office 100 and the optical network units 140, and N second-branch optical cables 124, 125 and 126 for connecting the 1 x N multiplexer/demultiplexer 114 to the optical network units 140. In this regard, the 1 x N multiplexer/demultiplexer 114 has a role of a remote node.

[0007] Since the optical distribution network 142 of the conventional WDM-PON has a double-branch structure including the first-branch optical cable 113, the second-branch optical cable 124-126 and the remote node 150, if the number of optical network units for the WDM-PON is N, all of the N optical network units 140 are connected to one remote node 150. Thus, the remote node 150 is located at a center of the N optical network units in order to minimize an amount of optical cables (i.e., optical fibers) to be used. However, if it is difficult to install the remote node 150 at the center of the N optical network units 140 due to geographic or local characteristics, the remote node 150 may be connected to the optical network units 140 through an inefficient structure, resulting in waste of expensive optical fibers. In particular, if the conventional WDM-PON having the two branches of optical distribution is applied to agricultural villages in which the optical network units 140 are sporadically distributed over the whole area of agricultural villages, optical fibers are unnecessarily wasted and installation work thereof is difficult.

SUMMARY

[0008] Various methods and apparatuses are described for a wavelength division multiplexing passive optical network (WDM-PON) that performs bi-directional communication. The WDM-PON may include two or more remote distribution nodes in between a central office and the most distant optical network unit. Each remote distribution node is located in a physically separate location. A first remote distribution node has two or more optical network units connected to the first remote distribution node. Each remote node separates one or more wavelength channels from a composite optical signal distributed through that remote distribution node.

[0009] Other features and advantages of the present invention will be apparent from the accompanying drawings and from the detailed description that follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate embodiment(s) of the invention and together with the description serve to explain some principles of the invention. In the drawings:

[0011] FIG. 1 is a block diagram showing a structure of a conventional WDM-PON.

[0012] FIG. 2 is a block diagram of a structure of a WDM-PON having a 1 x 2 x N/2 type division of wavelength channels with three-branches of optical distribution.

[0013] FIG. 3 is a block diagram of a structure of a WDM-PON having a 1 x 2 x N/2 type division of wavelength channels with three-branches of optical distribution.

[0014] FIG. 4 is a block diagram of a structure of a WDM-PON having a 1 x 4 x N/4 type division of wavelength channels with three-branches of optical distribution.

[0015] FIG. 5 is a block diagram of a structure of a WDM-PON having multiple branches of optical distribution employing an add/drop scheme.

DETAILED DESCRIPTION

[0016] In general, a composite optical signal that includes all of the wavelength channels in a first wavelength band is separated in a transmission path between a central office and the most distant optical network unit into two or more smaller groups consisting of subsets of the wavelength channels. The composite optical signal is sequentially separated along the transmission path two or more times to generate the

two or more smaller groups consisting of subsets of the wavelength channels. The WDM-PON may have multiple branches of optical distribution to overcome the structural problem of a double-branch optical distribution network. The WDM-PON may have multiple branches of optical distribution that can be easily installed while saving an amount of optical fibers to be used. The WDM-PON performs bi-directional communication.

[0017] Several example configurations of WDM-PONs will be described.

[0018] The WDM-PON may include a central office; a plurality of optical network units; and an optical distribution network physically connecting the central office to the optical network units and including at least two remote nodes that are physically separated from each other, and multiple branches of optical cable for sequentially connecting the central office, the remote nodes and the optical network units with each other.

[0019] The optical distribution network may include a first remote node, a second remote node located between the first remote node and the optical network units, and is provided with at least two multiplexers/demultiplexers, a first-branch optical cable for connecting the central office to the first remote node, a second-branch optical cable for connecting the first node to each of the multiplexers/demultiplexers of the

second node, and a third-branch optical cable for connecting the multiplexers/demultiplexers to the optical network units, respectively.

[0020] The first remote node transmits downstream signals of the central office to the multiplexers/demultiplexers of the second node by dividing the downstream signals into several signal groups, and transmits upstream signals of the multiplexers/demultiplexers of the second node to the central office by coupling the upstream signals with each other.

[0021] The multiplexers/demultiplexers may include 1 x N/2 multiplexers/demultiplexers, in which N is a number of optical network units.

[0022] The first remote node may include a division/coupling filter for dividing/coupling the upstream and downstream signals, a downstream signal division filter for dividing a downstream signal inputted thereto from the division/coupling filter into two or more subsets of wavelength channels in the downstream signal in order to output the subsets of wavelength channels to a predetermined multiplexer/demultiplexer. An upstream signal-coupling filter may receive subsets of wavelength channels in a different wavelength band from the multiplexers/demultiplexers in order to output the upstream signal to the division/coupling filter by combing the subsets of wavelength channels.

[0023] Alternatively, the first remote node may include an optical interleaver receiving the downstream signal from the central office. The

optical interleaver divides the downstream signal into odd wavelength channel signals and even wavelength channel signals in order to output the odd and even wavelength signals to a predetermined multiplexer/demultiplexer. The optical interleaver may receive the odd and even wavelength channel signals from the predetermined multiplexer/demultiplexer in order to couple the odd wavelength signals with the even wavelength signals and to transmit the coupled signals to the central office.

[0024] Alternatively, the optical distribution network may include at least one remote node connected to the multiple optical cables and having one or more drop filters for dropping a wavelength channel from a downstream signal, which is allocated to a predetermined optical network unit, into the predetermined optical network unit. The network may further include one or more add filters for adding an upstream signal, which is transmitted from the predetermined optical network unit, to the multiple optical cables. The WDM-PON further comprises a multiplexer/demultiplexer located between a final remote node and remaining optical network units in order to multiplex/demultiplex upstream and downstream signals.

[0025] FIG. 2 is a block diagram of a structure of a WDM-PON having a 1 x 2 x N/2 type division of wavelength channels with three branches of optical distribution.

[0026] Referring to FIG. 2, the WDM-PON includes a central office 200, an optical distribution network 242 and optical network units 240. The optical distribution network 242 physically connects the central office 200 to the optical network units 240 and includes two remote nodes and a triple-branch optical cable unit having first to third-branch optical cables connected to the remote nodes. Structures of the central office 200 and the optical network units 240 are similar to the structures of the central office and the optical network units shown in FIG. 1, so they will not be further described below in order to avoid redundancy.

[0027] In the three branches of optical distribution 242, a downstream signal transmitted from the central office 200, i.e., an optical signal having an A wavelength band, is transmitted to a first remote node 250 through a first-branch optical cable 214. Subsequently, the optical signal is split into a first subset of wavelength channels A+ and a second subset of wavelength channels A-, which are transmitted to first and second multiplexers/demultiplexers 208 and 209 of a second remote node 252 through two second-branch optical cables 215 and 216. Subsequently, the first and second multiplexers/demultiplexers 208 209 transmit optical signals having wavelengths that have been allocated for each subscriber to each optical network unit 240 by using N/2 third-branch optical cables 217 to 220.

[0028] In addition, an upstream signal transmitted from each optical network unit 240, i.e., an optical signal having a B wavelength band, is transmitted to the central office 200 through the second remote node 252 and the first remote node 250.

[0029] The first remote node 250 includes three A/B band division filters, i.e., first to third A/B band division filters 221, 224 and 225 for dividing a downstream optical signal having an A wavelength band and an upstream optical signal having a B wavelength band, an A+/A- band division filter 222 located among the first to third A/B band division filters 221, 224 and 225 in order to divide the downstream optical signal having the A wavelength band into a first subset of wavelength channels (A+ signal), such as wavelength channels 1-16, and a second subset of wavelength channels (A- signal), such as wavelength channels 17-32. The B+/B- band coupling filter 223 may be located among the first to third A/B band division filters 221, 224 and 225. The +/B- band coupling filter 223 couples a third subset of wavelength channels (B+ signal) inputted from the first multiplexer/demultiplexer 208 with a fourth subset of wavelength channels (B- signal) inputted from the second multiplexer/demultiplexer 209.

[0030] Thus, the first remote node 250 has a series of band splitting filters 221, 224 and 225 configured to split a first composite optical signal that includes all of the wavelength channels in a first

wavelength band (i.e. downstream signal – "A") into a first subset of the wavelength channels (A+) and a second subset of the wavelength channels (A-).

[0031] The above division and coupling filters include thin film optical filters having a plurality of thin films, which are generally known in the art. Properties of the optical filters are disclosed in detail in Chapter 42 (Optical properties of films and coating) of "Handbook of Optics Volume 1" Bass, M., Van Stryland, E., Williams, D., and Wolfe, W. (eds), published by McGraw-Hill, New York, (1995).

[0032] The downstream signal transmitted from the central office 200, i.e., the optical signal having the A wavelength band, is transmitted to the A+/A- band division filter 222 through the first A/B band division filter 221 and is divided into the first subset of wavelength channels (A+ signal) and the second subset of wavelength channels (A- signal). Subsequently, the first subset of wavelength channels (A+ signal) is transmitted to the second A/B band division filter 225, and then transmitted to the first multiplexer/demultiplexer 208 of the second remote node 252 through the second-branch optical cable 215. In addition, the second subset of wavelength channels (A- signal) is transmitted to the third A/B band division filter 224, and then transmitted to the second multiplexer/demultiplexer 209 of the second remote node 252 through the second-branch optical cable 216. Thus, the downstream optical signals

inputted from the central office 200 are divided into two groups based on wavelengths thereof and transmitted to the first and second multiplexers/demultiplexers 208 and 209. In addition, the first subset of wavelength channels (A+ signal) passing through the first multiplexer/demultiplexer 208 is divided into signals having various individual wavelengths and transmitted to first to $(N/2)^{th}$ optical network units 240-1 to 240-N/2. The second subset of wavelength channels (A- signal) passing through the second multiplexer/demultiplexer 209 is divided into signals having various individual wavelengths and transmitted to $(N/2+1)^{th}$ to N^{th} optical network units 240-N/2+1 to 240-N.

[0033] In the meantime, the upstream signal inputted from each optical network unit 240, i.e., the optical signal having the B wavelength band, is transmitted in an opposite direction to the above manner. That is, the first multiplexer/demultiplexer 208 multiplexes a third subset of wavelength channels (B+ signals) inputted thereto from the first to $(N/2)^{th}$ optical network units 240-1 to 240-N/2 and transmits the multiplexed signals to the first remote node 250 through the second-branch optical cable 215. In addition, the second multiplexer/demultiplexer 209 multiplexes a fourth subset of wavelength channels (B- signals) inputted thereto from the $(N/2+1)^{th}$ to N^{th} optical network units 240-N/2+1 to 240-N and transmits the multiplexed signals to the first remote node 250 through the second-branch optical cable 216. After that, the third subset of

wavelength channels (B+ signals) inputted from the first multiplexer/demultiplexer 208 are transmitted to the B+/B- band coupling filter 223 through the second A/B band division filter 225 and the fourth subset of wavelength channels (B- signals) inputted from the second multiplexer/demultiplexer 209 are transmitted to the B+/B- band coupling filter 223 through the third A/B band division filter 224. Thereafter, the third subset of wavelength channels (B+ signals) are coupled with the fourth subset of wavelength channels (B- signals) at the B+/B- band division filter 222 and transmitted to the central office 200 through the first A/B band division filter 221.

[0034] Thus, the series of band splitting filters 221-225 are also coupled together to create a second composite optical signal that includes all of the wavelength channels in a second wavelength band (i.e. upstream signal (B) by combining a first portion of the wavelength channels (B+) in the second B wavelength band and a second portion of the wavelength channels (B-) in the second B wavelength band. The second composite optical signal travels in the opposite direction of the first composite optical signal and occupies a different wavelength band than the first composite optical signal.

[0035] The second remote node 252 contains a first multiplexer/demultiplexer 208 to receive a first subset of the wavelength channels (A+) in a first composite optical signal (A) from the first remote

node 250 and to send the first portion of wavelength channels (B+) in a second composite optical signal B to the first remote node. The second remote node 252 also contains a second multiplexer/demultiplexer 209 to receive a second subset of the wavelength channels (A-) in the first composite optical signal (A) from the first remote node 250 and to send the second portion (B-) of the second B wavelength band to the first remote node 252. As discussed, the first multiplexer/demultiplexer 208 and second multiplexer/demultiplexer 209 may be located in separate physical localities as well as the remote nodes 250, 252 may be located in separate physical localities.

[0036] Herein, the first and second multiplexers/demultiplexers 208 and 209 of the second remote node can be installed in various positions while being physically separated from each other. Thus, the remote node can be located in an effective position by taking distribution of the optical network units into consideration.

[0037] In addition, the first and second multiplexers/demultiplexers 208 and 209 can be embodied in the form of arrayed waveguide grating (AWG). The AWG is generally known in the art. In particular, the AWG is disclosed in detail in the document "Transmission characteristic of arrayed-waveguide N x N wavelength multiplexer" (Journal of Lightwave Technology, volume 13, pages 447 to 455, Mar. 1995).

[0038] Preferably, the first and second multiplexers/demultiplexers 208 and 209 can be embodied by means of a filter-type dense wavelength-division multiplexing multiplexer/demultiplexer.

[0039] FIG. 3 is a block diagram of a structure of a WDM-PON having a 1 x 2 x N/2 type division of wavelength channels with three branches of optical distribution.

[0040] Referring to FIG. 3, the WDM-PON includes a central office 300, an optical distribution network 342 and optical network units 340. The optical distribution network 342 physically connects the central office 300 to the optical network units 340 and includes first and second remote nodes 350 and 352 and a triple-branch optical cable unit having first to third-branch optical cables connected to the remote nodes 350 and 352. Herein, structures of elements similar to those shown in FIG. 1 will not be further described below in order to avoid redundancy.

[0041] The first remote node 350 includes an optical interleaver 321 for dividing a downstream signal inputted thereto from a first-branch optical cable 334 into odd optical wavelength signals and even optical wavelength signals. Thus, the first remote node 350 has an optical interleaver 321 configured to split a first composite optical signal in a first wavelength band (i.e. downstream signal – "A") into a first portion (A+) consisting of odd numbered wavelength channels and a second portion (A-) consisting of odd numbered wavelength channels. As generally

known in the art, the optical interleaver 321 is an optical device for outputting optical signals by dividing the optical signals according to wavelengths or frequencies thereof.

[0042] A basic principle of the optical interleaver 321 is similar to a principle of a Mach Zhender optical interferometer, in which inputted optical signals are divided while passing through a 2 x 2 optical coupler having two inputs and two outputs and coupled with each other in the 2 x 2 optical coupler after traveling along two different optical paths, so that signals having uniform frequency intervals are separately outputted through two output ports. For instance, if N optical signals are inputted into the optical interleaver 321 with an interval of 100GHz, optical signals of a +100GHz, a +300GHz... are outputted through a first output port 316a and optical signals of a +200GHz, a +400GHz... are outputted through a second output port 317b. In this regard, "a" is a predetermined band frequency of an optical signal. Thus, the N optical signals inputted with an interval of 100GHz are divided into two signal groups with an interval of 200GHz and N/2 optical signals are outputted through two output ports 316a and 317b, respectively. At this time, the optical signals outputted from the first output port 316a are defined as odd optical wavelength channel signals and the optical signals outputted from the second output port 317b are defined as even optical wavelength channel signals.

[0043] Accordingly, the optical signals inputted through the first-branch optical cable 334 are divided into odd optical wavelength channels and even optical wavelength channels at the optical interleaver 321 of the first remote node 350. Subsequently, the odd optical wavelength channels are outputted through the first output port 316a and transmitted to a first multiplexer/demultiplexer 314 through the second-branch optical cable 316, and the even optical wavelength channels are outputted through the second output port 317b and transmitted to the second multiplexer/demultiplexer 315 through the second-branch optical cable 317.

[0044] In addition, the first and second multiplexers/demultiplexers 314 and 315 divide the subsets of odd and even optical wavelength channels into signals having various wavelengths and transmit them to each optical network unit.

[0045] For the present embodiment, odd optical network units are connected to the first multiplexer/demultiplexer 314 and even optical network units are connected to the second multiplexer/demultiplexer 315 for illustration purposes.

[0046] Although the above description has been made in relation to the downstream signal transmitted to the optical network unit 340 from the central office 300, it is noted that the upstream signal is transmitted to the central office 300 from the optical network units 340 through a

predetermined transmission procedure in an order reverse to that of the transmission procedure of the downstream signal. Thus, the second remote node 352 contains a first multiplexer/demultiplexer 314 that receives the odd numbered wavelength channels from the first remote node 350 and sends the first portion (B+) of the wavelength channels in the second wavelength band (B) to the first remote node 350. The second remote node 352 also contains a second multiplexer/demultiplexer 315 that receives the second even wavelength portion (A-) of the first A wavelength band from the first remote node 350 and sends the second even wavelength portion (B-) of the second B wavelength band to the first remote node 350. The optical interleaver 312 is also configured to create a second composite optical signal in a second wavelength band (i.e. upstream signal - "B") from a combination of a first portion of wavelength channels (B+) in the second wavelength band (B) and a second portion of wavelength channels (B-) in the second wavelength band (B). Herein, the upstream signals outputted from the first multiplexer/demultiplexer 314 are coupled with the downstream signals outputted from the second multiplexer/demultiplexer 315 at the optical interleaver 321 of the first remote node and then transmitted to the central office 300.

[0047] FIG. 4 is a block diagram of a structure of a WDM-PON having a 1 x 4 x N/4 type division of wavelength channels with three-branches of optical distribution.

[0048] Referring to FIG. 4, the WDM-PON includes a central office 400, an optical distribution network 442 and optical network units 440. The optical distribution network 442 physically connects the central office 400 to the optical network units 440 and includes first and second remote nodes 450 and 452 and a triple-branch optical cable unit having first to third-branch optical cables connected to the remote nodes 450 and 452.

[0049] The first remote node 450 includes first to fifth optical filters 404, 405, 406, 407 and 408 for coupling/decoupling the downstream signal having an A wavelength band to/from the upstream signal having a B wavelength band, a demultiplexer 402 for dividing the downstream signal having the A wavelength band into four subsets of wavelength channels, and a multiplexer 403 for coupling four subsets of wavelength channels having the B wavelength band and transmitting them to the central office 400.

[0050] The downstream signal of the central office 400, i.e., the multiplexed optical signal having the A wavelength band is transmitted to a first optical filter 404 through a first-branch optical cable 401, and then transmitted to the demultiplexer 402. Upon receiving the multiplexed optical signal, the demultiplexer 402 divides the multiplexed optical signal having the A wavelength band into four subsets of wavelength channels and transmits them into the second to fifth optical filters 405, 406, 407 and 408.

[0051] For instance, if the number of optical network units are 32 (N=32) and 32 channels with a predetermined frequency internal are inputted into the demultiplexer 402 corresponding to the number of optical network units, optical signals of a +100GHz, a +200GHz,... a +700GHz and a +800GHz are outputted through the second optical filter 405, optical signals of a +1100GHz, a +1200GHz,... a +1700GHz and a +1800GHz are outputted through the third optical filter 406, optical signals of a +2100GHz, a +2200GHz,... a +2700GHz and a +2800GHz are outputted through the fourth optical filter 407, and optical signals of a +3100GHz, a +3200GHz,... a +3700GHz and a +3800GHz are outputted through the fifth optical filter 408. In this regard, "a" is a predetermined band frequency of an optical signal. Further, the optical signal having the A wavelength band can be divided into four subsets of wavelength channels; however, the present invention is not limited to the above manner.

[0052] Subsequently, the optical signal that has been transmitted to the second optical filter 405 is transmitted to a first multiplexer/demultiplexer 413 of the second remote node 452 through a second-branch optical cable 409. In the same manner, the optical signals that have been transmitted to the third through fifth optical filters 406, 407 and 408 are transmitted to the second through fourth multiplexers/demultiplexers 414, 415, and 416 via second-branch optical

cables 410, 411, 412, respectively. Thus, the downstream optical signals of the central office 400 are divided into four subsets of wavelength channels and distributed into four multiplexers/demultiplexers. In addition, the optical signal inputted into the first multiplexer/demultiplexer 413 through the second-branch optical cable 409 is divided into signals having various wavelengths by means of the first multiplexer/demultiplexer 413 and is transmitted into a first group of optical network units 440-1 to 440-N/4 through N/4 third-branch optical cables 417 and 418. In the same manner, the optical signals inputted into the second to fourth multiplexers/demultiplexers 414 to 416 through optical cables 410, 411, 412 are divided into signals having various wavelengths by means of the second to fourth multiplexers/demultiplexers 414 to 416 and are transmitted into second to fourth groups of optical network units through N/4 third-branch optical cables 419-424.

[0053] Thus, the first remote node 450 has a first multiplexer/demultiplexer 402 coupled to two or more band splitting filters 405-408 configured to split a first composite optical signal that includes all of the wavelength channels in a first wavelength band (i.e. downstream signal A) into a first subset of wavelength channels (A+) and a second subset of wavelength channels (A-). The first band splitting filter 404 separates and couples a downstream and an upstream optical signal onto the same optical cable connected to the central office 400. The first 1 x

N multiplexer/demultiplexer 402 outputs N wavelength channels, where N is a subset of the total number of subscribers coupled in the optical data path of the first 1 x N multiplexer/demultiplexer 402.

[0054] The second remote node 452 contains a first multiplexer/demultiplexer 413 that receives the first subset of wavelength channels from the first remote node 450, a second multiplexer/demultiplexer 414 to receive the second subset of wavelength channels from the first remote node 450, a third multiplexer/demultiplexer 415 to receive the third wavelength portion (A+) of the first A wavelength band from the first remote node 450, and a fourth multiplexer/demultiplexer 416 to receive the fourth wavelength portion (A+) of the first A wavelength band from the first remote node 450.

[0055] The upstream signal transmitted from each optical network unit 440, i.e., the optical having the B wavelength band, is transmitted from the optical network unit 440 to the central office 400 through a predetermined transmission procedure in an order reverse to that of the transmission procedure of the downstream signal. Herein, four upstream subsets of wavelength channels that have the B wavelength band and that are inputted into the second to fifth optical filters 405 to 408 through second-branch optical cables 409-412 are transmitted to the central office 400 through the first optical filter 404 after being multiplexed by means of the multiplexer 403 of the first remote node 450.

[0056] The demultiplexer 402 and the multiplexer 403 of the first remote node and the first to fourth multiplexers/demultiplexers 413 to 416 of the second remote node 452 may be embodied in the form of AWGs or 8-skip-2 optical fibers. Thus, the second remote node 452 sends the first through the fourth subsets of the wavelength channels in a second B wavelength band to a second multiplexer/demultiplexer 403 in the first remote distribution node 450 via the band splitting filters 405-408. The second multiplexer/demultiplexer 403 combines the wavelength channels from the first through the fourth subsets of the wavelength channels.

[0057] FIG. 5 is a block diagram of the structure of a WDM-PON having multiple branches of optical distribution employing an add/drop scheme.

[0058] First, the present embodiment will be described in relation to a downstream signal transmitted to each optical network unit 540 from a central office 500.

[0059] The composite optical signal having all of the various wavelength channels from the central office 500 are transferred to a first remote node 550 through a first-branch optical cable 510. Herein, a downstream signal having a wavelength channel allocated to a first optical network unit 540-1 is dropped at a drop filter 501 of the first remote node 550 into an optical receiver 515 of the first optical network unit 540-1.

[0060] Subsequently, the optical signal having the remaining wavelength channels are transferred to a second remote node 554 through a second-branch optical cable 503. Herein, a downstream signal having a second wavelength channel allocated to a second optical network unit 540-2 is dropped at a first drop filter 503 of the second remote node 554 into an optical receiver 516 of the second optical network unit 540-2. In addition, a downstream signal having a third wavelength channel allocated to a third optical network unit 540-3 is dropped at a second drop filter 505 of the second remote node 554 into an optical receiver 517 of the third optical network unit 540-3.

[0061] Further, the optical signal having the remaining wavelength channels are transmitted to a multiplexer/demultiplexer 509 through a third-branch optical cable 512. Herein, the optical signals are divided into signals having wavelength channels allocated to optical network units and transmitted to each of the optical network units 540-4 and 540-N.

[0062] Thus, the third remote node 552 includes a first multiplexer/demultiplexer 509 and a first remote node 550 includes at least one add drop module501, 502. A first drop module 501 removes a wavelength channel from a composite optical signal that includes all of the wavelength channels. The first multiplexer/demultiplexer 509 distributes two or more of the wavelength channels in the composite optical signal to the optical network units 540-4 –540-N.

[0063] In addition, when the upstream signal is transmitted to the central office 500 from the optical network unit 540, an optical signal outputted from an optical transmitter 520 of the first optical network unit 540-1 is added at an add filter 502 of the first remote node 550, and then transmitted to the central office 500 through the first-branch optical cable 510.

[0064] Similarly, optical signals outputted from second and third optical network units 540-2 and 540-3 are added at first and second add filters 504 and 506 of the second remote node 554, and then transmitted to the central office 500. In addition, the remaining optical signals outputted from fourth and N^{th} optical network units 540-4 and 540-N are transmitted to the central office 500 through the multiplexer/demultiplexer 509 in the same manner as described above.

[0065] Preferably, the add/drop filters of the remote nodes are connected to optical transmitters/receivers of the optical network units through separate optical cables.

[0066] Thus, two or more add/drop modules 501-506 couple to an optical fiber from the central office 500 to the third remote node 552 containing a first multiplexer/demultiplexer 509. The add/drop modules 501, 503, 505 remove wavelength channels from the downstream optical signal prior to the first multiplexer/demultiplexer 509. The add/drop

modules 502, 504, 506 add wavelength channels to the upstream signal after the first multiplexer/demultiplexer 509.

[0067] Although the present embodiment has been described in relation to three optical network units outputting optical signals being added or dropped at add filters or drop filters, the present invention does not limit the number of optical network units outputting optical signals being added or dropped. In other words, the add/drop operation can be carried out in relation to all optical network units.

[0068] As described above, since the optical distribution network of the WDM-PON includes a plurality of remote nodes and multiple branch optical cables, the optical distribution network can be effectively located in a region in which optical network units are sporadically distributed over the whole area of the region. Thus, the distance between the remote node and the optical network unit is shortened so that it is possible to save an amount of optical fibers to be used. In addition, since the distance between the remote node and the optical network unit becomes shortened, installation work for the optical distribution network can be easily carried out.

[0069] With respect to large cities in which the optical network units are concentrated, the optical distribution network is generally installed by using cables buried in the ground. However, as the number of optical distribution networks increases, it is difficult to cover the optical

distribution networks with existing cables buried in the ground. The optical distribution network having the multiple branch structure according to the present invention can reduce the amount of optical fibers to be buried in the ground, so it is possible to effectively manage existing cables buried in the ground.

[0070] In addition, because the WDM-PON includes a plurality of remote nodes, the WDM-PON can be effectively installed at a desired location with various alignments by taking geographic features into consideration.

[0071] In the forgoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustration rather than a restrictive sense.

What is claimed is:

1. A wavelength division multiplexing passive optical network (WDM-PON) for performing bi-directional communication, the WDM-PON comprising:

two or more remote distribution nodes in between a central office and a first optical network unit, each remote distribution node located in a physically separate location and a first remote distribution node has two or more optical network units connected to the first remote distribution node, wherein each remote distribution node separates one or more wavelength channels from a composite optical signal distributed through that remote distribution node.

2. The WDM-PON of claim 1, further comprising:

a first remote distribution node having a series of band splitting filters configured to split a first composite optical signal that includes all of the wavelength channels in a first wavelength band into a first subset of the wavelength channels and a second subset of the wavelength channels.

3. The WDM-PON of claim 2, wherein the series of band splitting filters are also coupled together to create a second composite optical

signal in a second wavelength band by combining a first portion of the wavelength channels in the second wavelength band and a second portion of the wavelength channels in the second wavelength band, wherein the second composite optical signal travels in the opposite direction of the first composite optical signal and occupies a different wavelength band than the first composite optical signal.

4. The WDM-PON of claim 1, further comprising:

a second remote distribution node containing a first multiplexer/demultiplexer to receive a first subset of the wavelength channels in a first composite optical signal from the first remote distribution node and to send a first portion of wavelength channels in a second composite optical signal to the first remote distribution node, wherein the second composite optical signal occupies a different wavelength band than the first composite optical signal.

5. The WDM-PON of claim 4, wherein the second remote distribution node also contains a second multiplexer/demultiplexer to receive a second subset of the wavelength channels in the first composite optical signal from the first remote distribution node and to send a second subset of wavelength channels from the second wavelength band to the first remote distribution node.

6. The WDM-PON of claim 1, further comprising:

a first remote distribution node having an optical interleaver configured to split a first composite optical signal in a first wavelength band into a first portion consisting of odd numbered wavelength channels and a second portion consisting of odd numbered wavelength channels.

7. The WDM-PON of claim 6, wherein the optical interleaver is also configured to create a second composite optical signal in a second wavelength band from a combination of a first portion of wavelength channels in the second wavelength band and a second portion of wavelength channels in the second wavelength band.

8. The WDM-PON of claim 1, wherein the first remote distribution node includes an optical interleaver to receiving a downstream optical signal from the central office, divides the downstream signal into odd wavelength channel signals and even wavelength channel signals in order to output the odd and even wavelength signals to corresponding multiplexer/demultiplexers, and receives the odd and even wavelength channel signals from the corresponding multiplexer/demultiplexers in order to combine the odd wavelength channel signals with the even wavelength channel signals.

9. The WDM-PON of claim 6, further comprising:

a second remote distribution node containing a first multiplexer/demultiplexer to receive the odd numbered wavelength channels from the first remote distribution node and to send the first portion of the wavelength channels in a second wavelength band to the first remote distribution node.

10. The WDM-PON of claim 9, wherein the second remote distribution node also containing a second multiplexer/demultiplexer to receive the even numbered wavelength channels of the first wavelength band from the first remote distribution node and to send a portion of the second wavelength band to the first remote distribution node.

11. The WDM-PON of claim 1, further comprising

a first remote distribution node having a multiplexer/demultiplexer coupled to two or more band splitting filters configured to split a first composite optical signal that includes all of the wavelength channels in a first wavelength band into a first subset of wavelength channels and a second subset of wavelength channels.

12. The WDM-PON of claim 11, further comprising:

a second remote distribution node containing a first multiplexer/demultiplexer to receive the first subset of wavelength channels from the first remote distribution node, a second multiplexer/demultiplexer to receive the second subset of wavelength channels from the first remote distribution node.

13. The WDM-PON of claim 12, wherein the second remote distribution node to send a first through the fourth portions of the wavelength channels in a second wavelength band to the second multiplexer/demultiplexer in the first remote distribution node via the band splitting filters, wherein the second multiplexer/demultiplexer to combine the wavelength channels from the first through the fourth portions.

14. The WDM-PON of claim 11, further comprising:

a first band splitting filter to separate and couple a downstream and an upstream optical signal onto a first optical cable connected to the central office.

15. The WDM-PON of claim 1, wherein the first remote distribution node includes a first multiplexer/demultiplexer and a second remote distribution node includes an add drop module, wherein a first drop module removes a wavelength channel from a composite optical signal

that includes all of the wavelength channels and the first multiplexer/demultiplexer distributes two or more of the wavelength channels in the composite optical signal.

16. The WDM-PON of claim 1, further comprising:

two or more add/drop modules coupled to an optical fiber from the central office to the first remote distribution node containing a first multiplexer/demultiplexer, wherein the add/drop modules to remove wavelength channels from a downstream optical signal prior to the first multiplexer/demultiplexer.

17. A method, comprising

separating a first composite optical signal that includes all of the wavelength channels in a first wavelength band in a transmission path between a central office and a most distant optical network unit into two or more smaller groups consisting of subsets of the wavelength channels; and

generating the two or more smaller groups consisting of subsets of the wavelength channels by sequentially separating the first composite optical signal along the transmission path two or more times.

18. The method of claim 17, further comprising:

separating the composite optical signal into a first subset that includes even numbered wavelength channels and a second subset that includes odd numbered wavelength channels.

19. The method of claim 17, further comprising:

combining two or more optical signals in a second wavelength band along the transmission path, each optical signal with one or more wavelength channels, wherein a second composite optical signal travels in an opposite direction of the first composite optical signal and occupies a different wavelength band than the first composite optical signal.

20. An apparatus, comprising:

a first optical network unit including an optical receiver and an optical transmitter; and

means for separating a first composite optical signal that includes all of the wavelength channels in a first wavelength band into two or more smaller groups consisting of subsets of the wavelength channels in a transmission path between a central office and a first optical network unit, wherein the first composite optical signal is sequentially separated along the transmission path two or more times to generate the two or more smaller groups consisting of subsets of the wavelength channels.

21. The apparatus of claim 20, further comprising:

means for separating the composite optical signal into a first subset that includes even numbered wavelength channels and a second subset that includes odd numbered wavelength channels.

22. The apparatus of claim 20, further comprising:

means for combining two or more optical signals in a second wavelength band along the transmission path, each optical signal with one or more wavelength channels, wherein a second composite optical signal travels in an opposite direction of the first composite optical signal and occupies a different wavelength band than the first composite optical signal.

ABSTRACT

Various methods and apparatuses are described for a wavelength division multiplexing passive optical network (WDM-PON) that performs bi-directional communication. The WDM-PON may include two or more remote distribution nodes in between a central office and the most distant optical network unit . Each remote distribution node is located in a physically separate location. A first remote distribution node has two or more optical network units connected to the first remote distribution node. Each remote node separates one or more wavelength channels from a composite optical signal distributed through that remote distribution node.

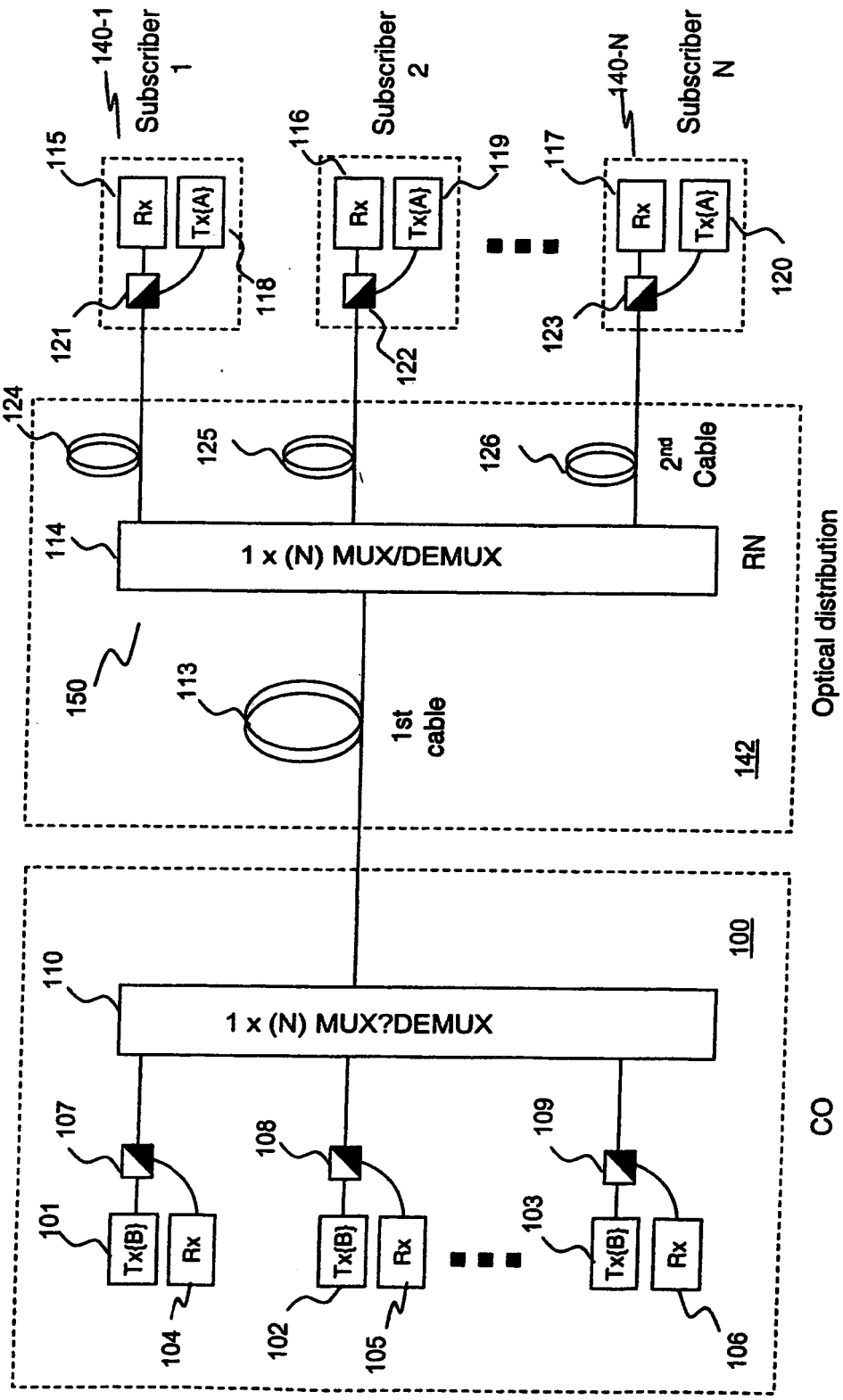
140-1
Subscriber 1
140-N
Subscriber N
Subscriber 2
115
116
117
119
Rx
Tx(A)
118
120
121
122
123
124
125
126
2nd Cable
114
1 x (N) MUX/DEMUX
RN
150
113
1st cable
142
Optical distribution networks
100
110
1 x (N) MUX?DEMUX
107
108
109
101
103
Tx(B)
Rx
104
102
105
106
CO

Figure 1

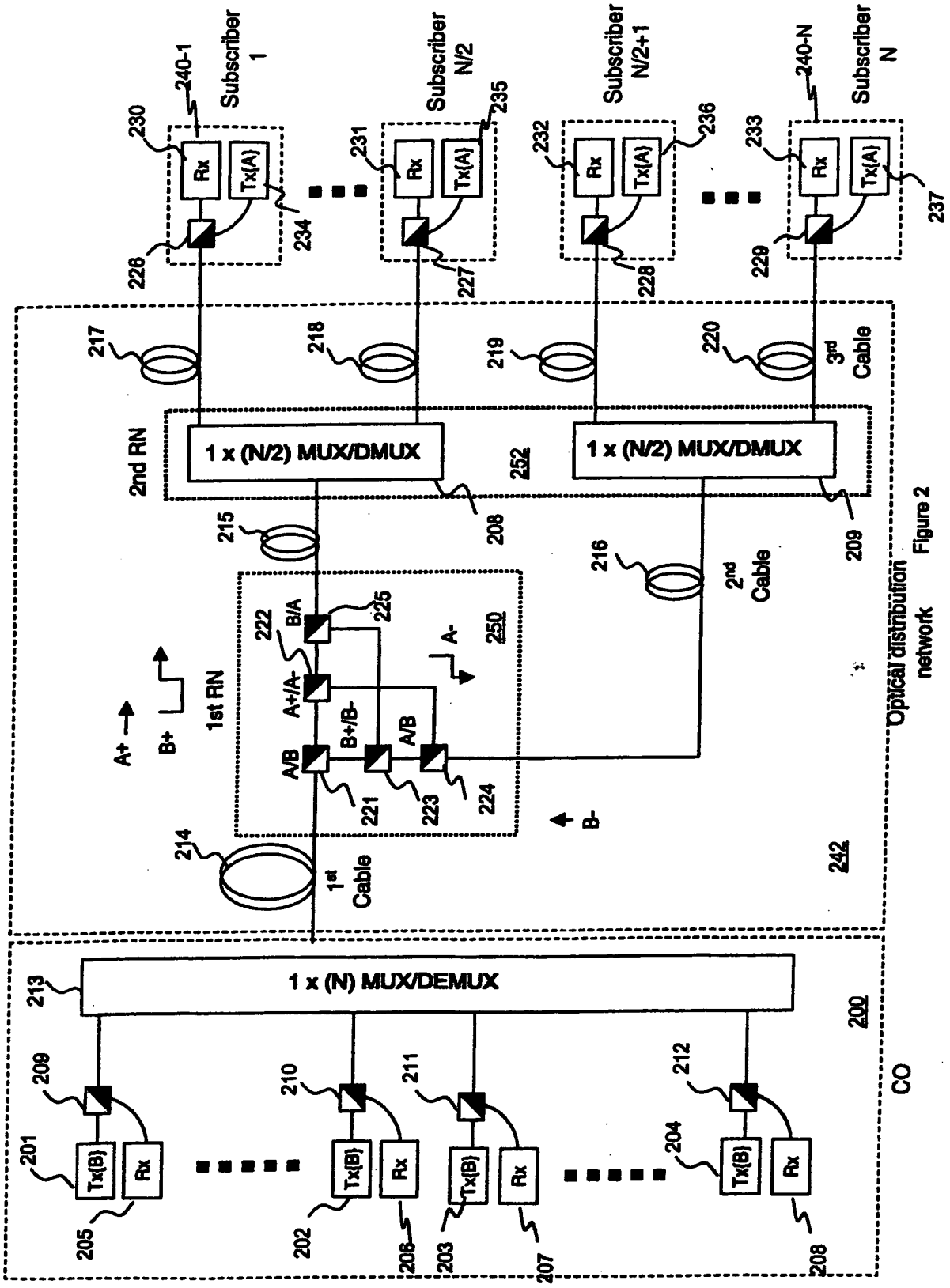
Subscriber 1
240-1
Subscriber N/2
Subscriber N/2+1
240-N
Subscriber N
Rx
Tx(A)
Tx(B)
230
231
232
233
234
235
236
237
226
227
228
229
217
218
219
220
3rd Cable
2nd RN
1 x (N/2) MUX/DMUX
252
208
209
215
216
2nd Cable
222
B/A
225
250
A-
A+/A-
B+/B-
A/B
A+
B+
1st RN
221
223
224
B-
214
1st Cable
242
Optical distribution network
1 x (N) MUX/DEMUX
213
200
CO
201
202
203
204
205
206
207
208
209
210
211
212

Figure 2

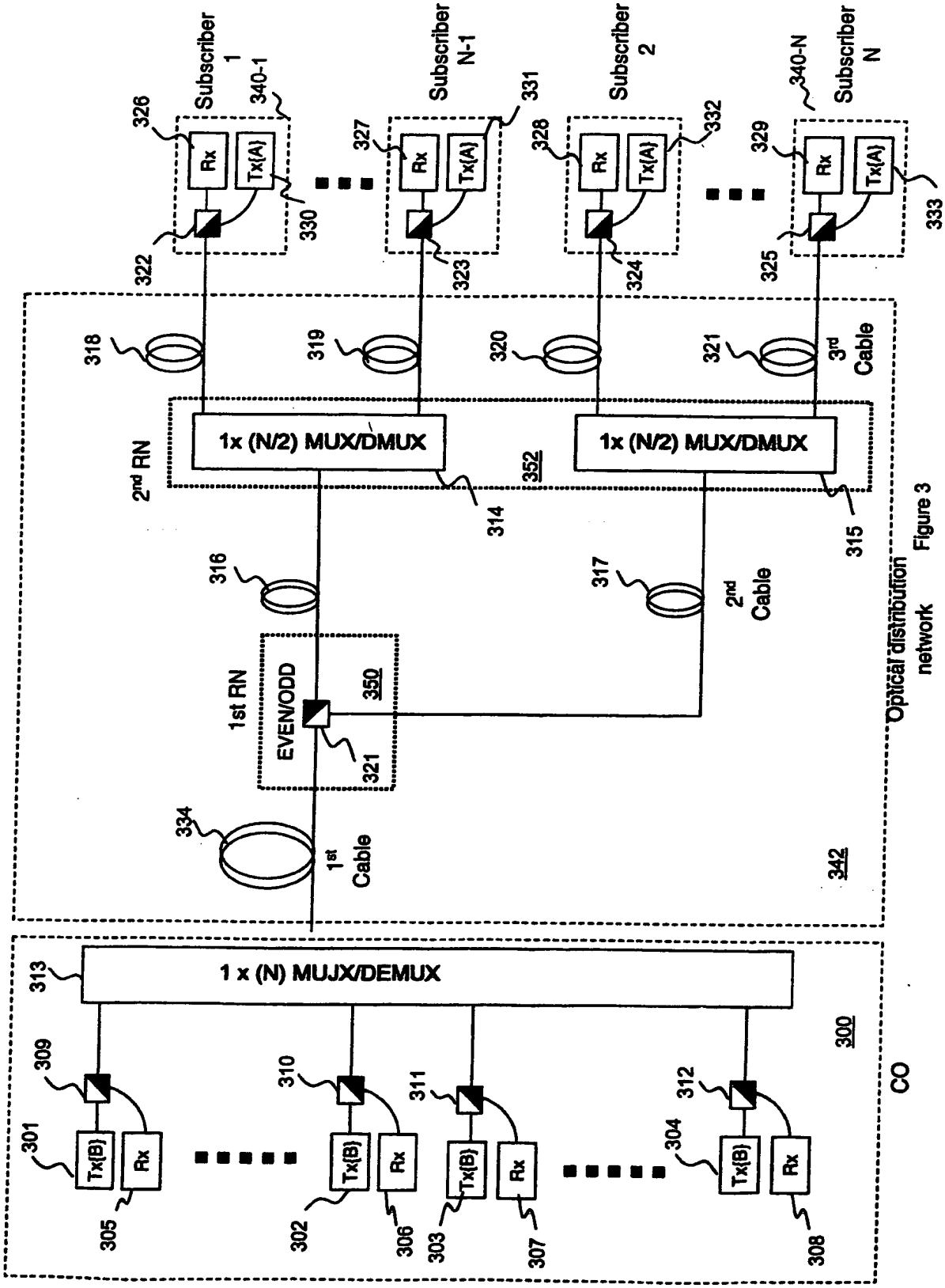
Subscriber 1
340-1
Subscriber N-1
Subscriber 2
340-N
Subscriber N
Rx
Tx(A)
326
327
328
329
330
331
332
333
322
323
324
325
318
319
320
321
3rd Cable
2nd RN
1x (N/2) MUX/DMUX
1x (N/2) MUX/DMUX
352
314
315
316
317
2nd Cable
1st RN
EVEN/ODD
350
321
334
1st Cable
342
Optical distribution network
1 x (N) MUJX/DEMUX
313
300
CO
309
310
311
312
301
304
Tx(B)
Rx
305
302
306
303
307
308

Figure 3

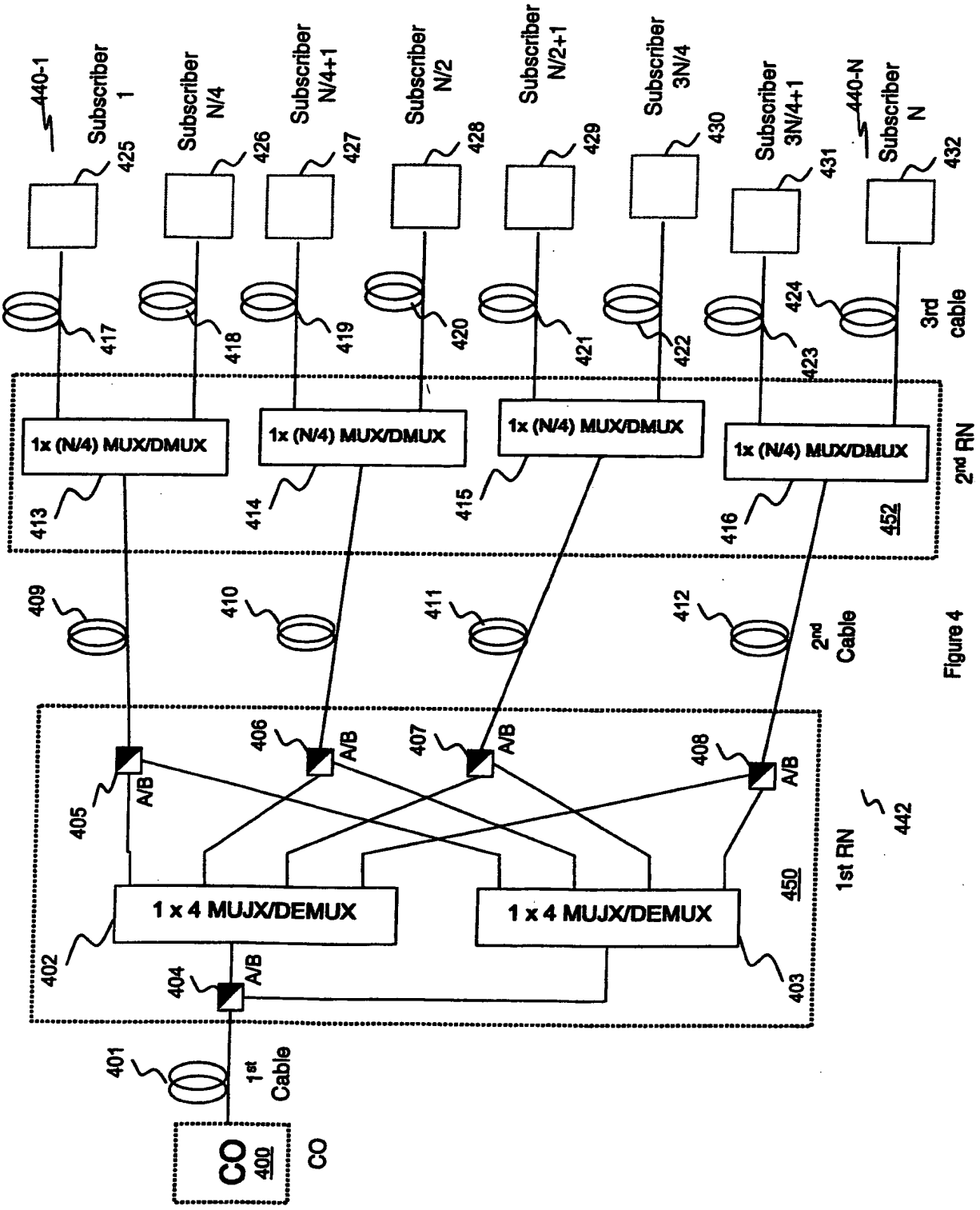
440-1
Subscriber 1
425
Subscriber N/4
426
Subscriber N/4+1
427
Subscriber N/2
428
Subscriber N/2+1
429
Subscriber 3N/4
430
Subscriber 3N/4+1
431
440-N
Subscriber N
432
417
418
419
420
421
422
423
424
3rd cable
1x (N/4) MUX/DMUX
413
1x (N/4) MUX/DMUX
414
1x (N/4) MUX/DMUX
415
1x (N/4) MUX/DMUX
416
452
2nd RN
409
410
411
412
2nd Cable
406
A/B
407
A/B
408
A/B
405
A/B
1 x 4 MUJX/DEMUX
402
1 x 4 MUJX/DEMUX
403
404
A/B
450
1st RN
442
401
1st Cable
CO
400
CO

Figure 4

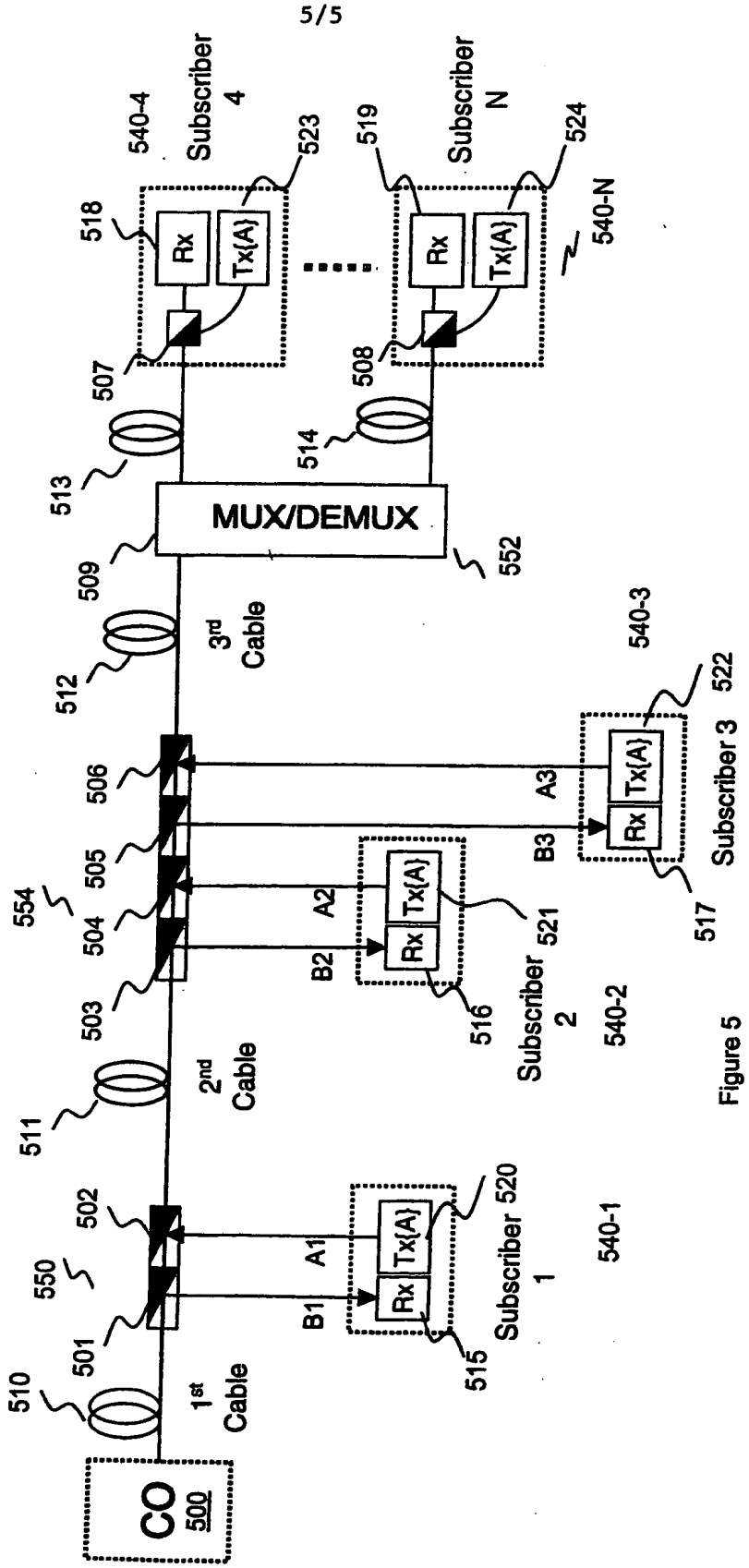
CO
500
1st Cable
2nd Cable
3rd Cable
MUX/DEMUX
552
Subscriber 1
Subscriber 2
Subscriber 3
Subscriber 4
Subscriber N
540-1
540-2
540-3
540-4
540-N
Rx
Tx(A)
A1
B1
A2
B2
A3
B3
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
550
554

Figure 5